



Image Science and Analysis Group
KX\Human Exploration Science Office
KAARES



Solar Array Mast Imagery Discussion for ISIW

NASA Johnson Space Center
Astromaterials Research and Exploration Science (ARES)
Image Science and Analysis Group (ISAG)
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January 2017



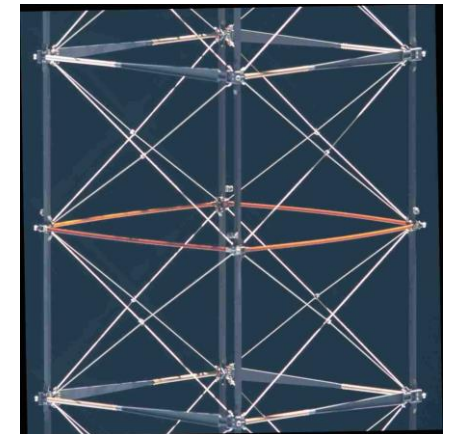
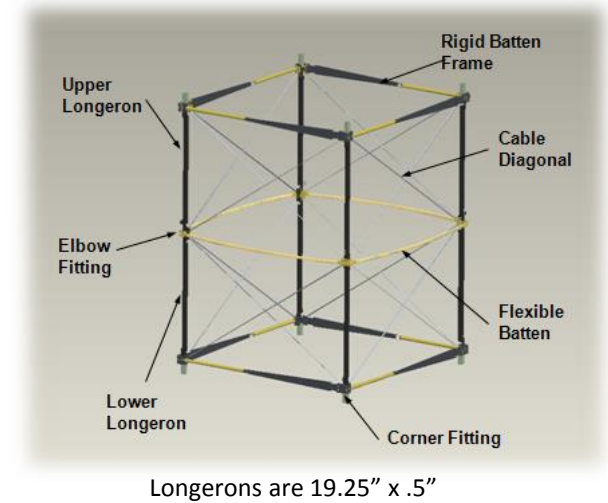
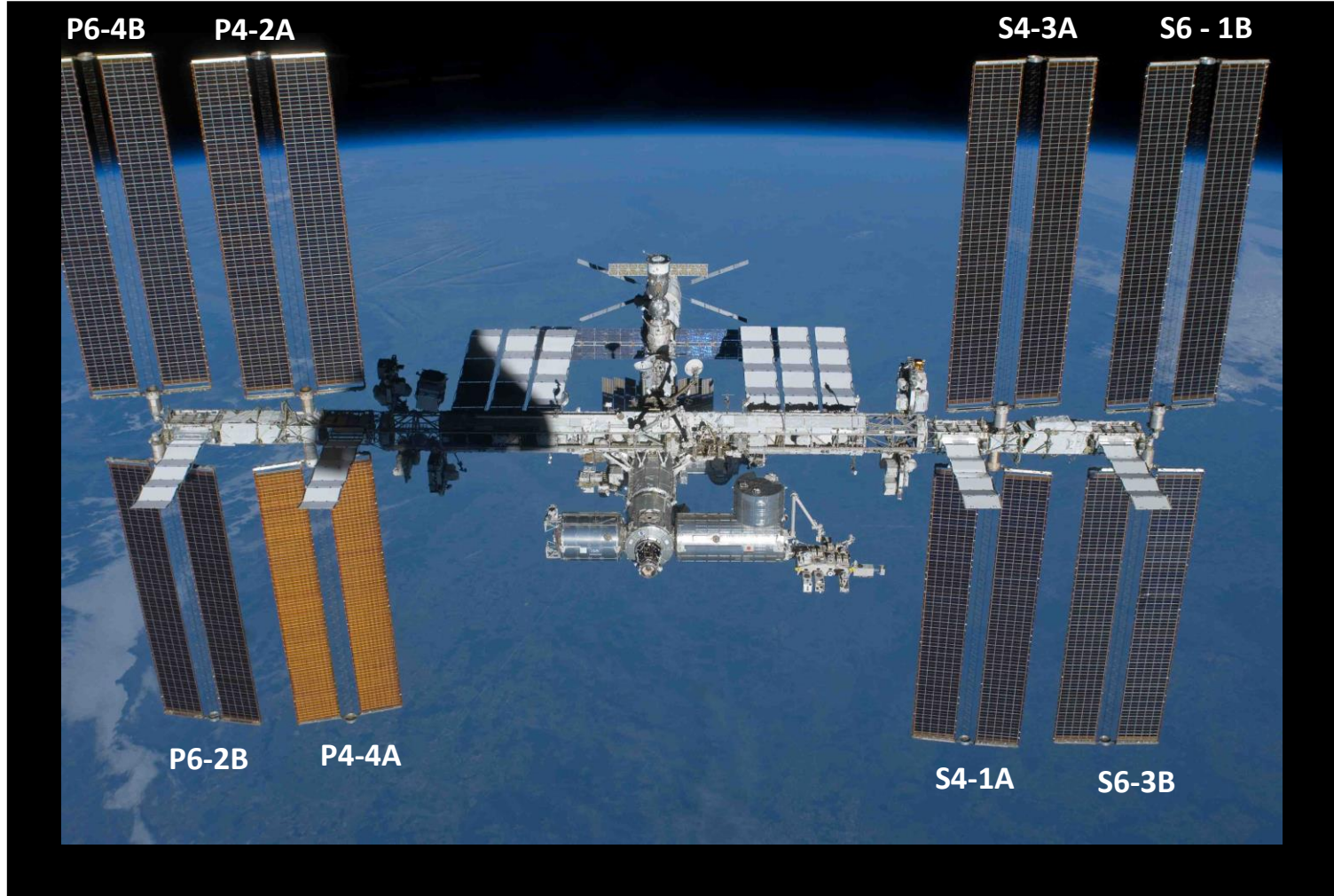
SAW Mast Inspection Back Ground

In 2012, NASA's Flight Safety Office requested the Micro Meteoroid and Orbital Debris (MMOD) office determine the probability of damage to the Solar Array Wing (SAW) mast based on the exposure over the life time of the ISS program.

As part of the risk mitigation of the potential MMOD strikes. ISS Program office along with the Image Science and Analysis Group (ISAG) began developing methods for imaging the structural components of the Mast.



What is a Solar Array Wing (SAW) Mast?





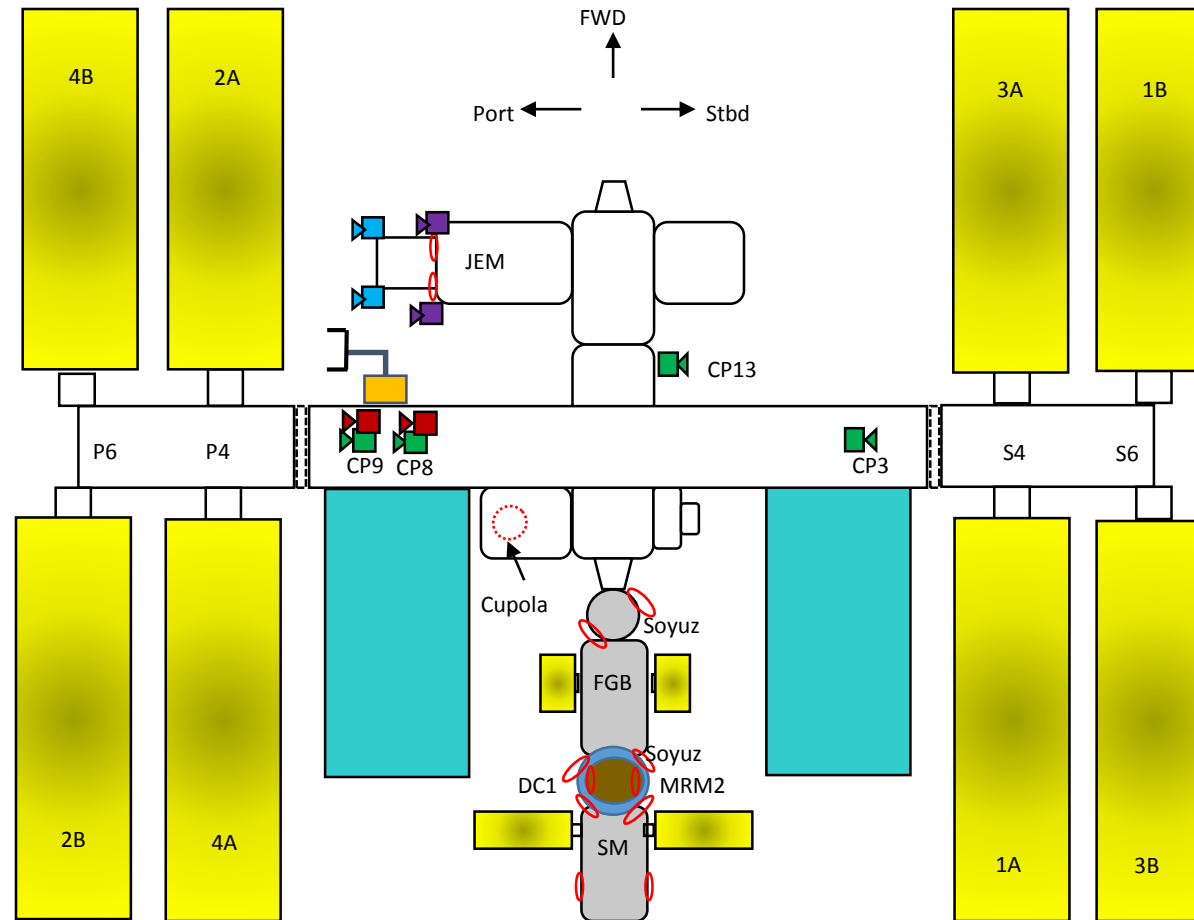
Viewing Options for SAW Mast

- External Cameras
 - External Television Cameras Group (ETVCG)
 - External High Definition Camera (EHDC)
 - Japanese Experiment Module (JEM) Cameras
 - Cameras on Robotic hardware
- Internal Cameras
 - Nikon Cameras (Nikon D4) with variety of lens
 - High Definition Camcorders



ISS Camera Port and Window Locations

- EHDC Camera (attached to ETVCG)
- ETVCG Cameras
- JEM Ext Cameras (Fwd and Aft)
- JEF Ext Cameras (Fwd and Aft)
- SSRMS with SPDM





ETVCG/EHDC Solar Array Viewing Assessment

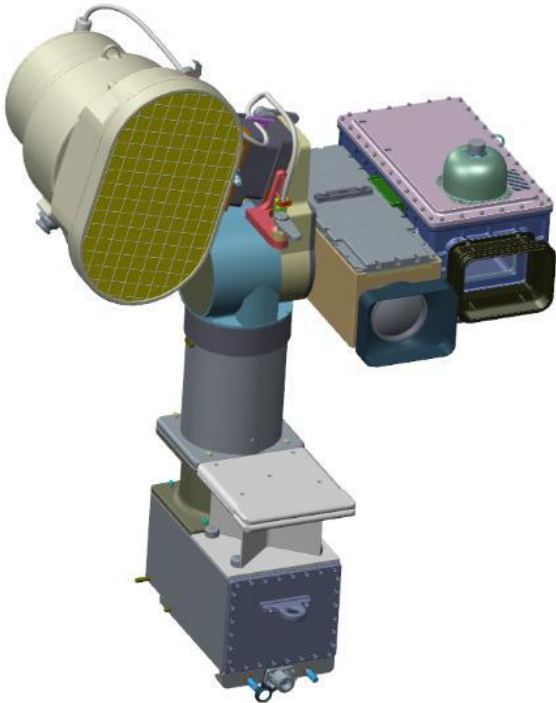


- Table below shows the solar array viewing capabilities at the current ETVCG locations. **This** may require maneuvering of the **solar array**.

- Yes

- Provides coverage from tip to base
- Yes

- Provides partial coverage of array

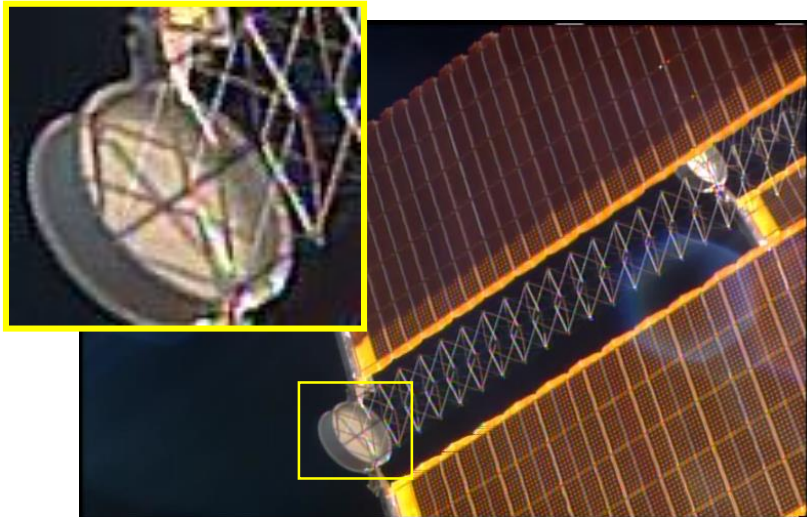


	1A/3A		3B/1B		4A/2A		2B/4B	
<u>Location</u>	Tip	Base	Tip	Base	Tip	Base	Tip	Base
CP3 (Looking Fwd)	Yes	Yes	Yes	No	No	No	No	No
CP3 (Looking Aft)	Yes	No	Yes	Yes	No	No	No	No
CP8 (Looking Fwd)	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
CP8 (Looking Aft)	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
CP9 (Looking Fwd)	Yes	No	Yes	No	Yes	Yes	Yes	No
CP9 (Looking Aft)	No	No	No	No	Yes	No	Yes	No
CP13	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No



ETVCG Solar Array Viewing Assessment

- To support this action, two mast surveys were performed.
 - Utilized standard definition TV cameras at CP3 (S1LOB) and CP9 (P1LOB) to view the adjacent masts S4 and P4.
- An analyst screened the recorded video and enhanced video frame grabs.



CP3 View of S4 Array



CP9 View of P4 Array (enhanced)

- **Results:**
 - **No mast damage was evident from review of the S4 and P4 survey video, however the review is considered incomplete due to low video resolution..**
 - **Damage detection is limited to “severe” MMOD damage evident by a longeron or batten being completely separated and out of normal orientation with multiple surveys.**
 - **It is the conclusion of the Image Science and Analysis Group that ETVCG video is not adequate to accomplish a risk mitigation survey.**



EHDC Viewing of SAW Mast



CP8-based view, looking starboard along truss



CP8-based view, looking starboard along truss
at Solar Array's

An issue with using External HD Camera to take SAW mast images is the time it takes to transfer an image to the ground.



Handheld Still Camera Viewing Assessment



- Table below shows which windows can be used to survey SAW masts



- Designates recommended windows with line of sight viewing



- Designates line of sight viewing, but less desirable due to loss of resolution through scratch panes or Soyuz access coordination.



- Views available after PMM relocate, but less desirable due to loss of resolution through scratch panes.

	S6		S4		P4		P6	
	3B/1B		1A/3A		4A/2A		2B/4B	
<u>ISS Windows</u>	TIP	BASE	TIP	BASE	TIP	BASE	TIP	BASE
JEM Aft	No	No	No	No	Yes	Yes	Yes	Yes
JEM Fwd	No	No	No	No	Yes	Yes	Yes	Yes
DC1- FWD*	No	No	No	No	Yes*	Yes*	Yes*	Yes*
MRM 2 - FWD	Yes	Yes	Yes	Yes	No	No	No	No
Soyuz on MRM 2 - Stbd	No	No	No	No	Yes	Yes	Yes	Yes
Soyuz on MRM 2 - Port	Yes	Yes	Yes	Yes	No	No	No	No
Cupola W1	No	No	No	No	Yes	Yes	Yes	Yes
Cupola W2	No	No	No	No	Yes	No	Yes	No
Cupola W3	Yes	No	Yes	No	No	No	No	No
Cupola W4	Yes	No	Yes	No	No	No	No	No
Cupola W5	No	No	No	No	No	No	No	No
Cupola W6	No	No	No	No	No	No	No	No
SM 1	No	No	No	No	Yes	Yes	Yes	Yes
SM 2	Yes	Yes	Yes	Yes	No	No	No	No
SM 3 through SM 14**	No	No**	No	No**	No	No**	No	No**

* - DC1 views will not be available once Multi-Purpose Module (MLM) is installed

** - SM window 13 and 14 provide views but require removal of SM hardware to access.



Hand Held Camera Viewing Assessment

- A hand held digital still camera (e.g. Nikon D2Xs/D4) with the appropriate lens (400mm preferred) will provide the resolution needed to detect “severe” damage for detailed analysis of failed battens, longerons, cable diagonals as well as “critical” areas of interest such as stress fractures and minor MMOD impact sites.
- Crew time required:
 - Camera set-up is ~10 minutes.
 - Photo survey is < 5 minutes per SAW Mast:
 - Increment 35 example:
 - Nikon D2Xs w/180mm Lens – 1 minute (22 and 34 pictures)
 - Increment 38 example:
 - Nikon D2Xs w/400mm – 1.5 to 2 Minutes (~ 40 pictures)
 - Increment 41 example:
 - Nikon D4 w/400mm - 1.5 to 2 Minutes (~ 45 pictures)
- Photo acquisition should be scheduled on crew’s timeline to ensure SAWs are in viewing position and there is no blockage from thermal radiators, Service Module solar array and inboard solar array.



Handheld Camera SAW Mast Surveys To Date

- Increment 35 (May 11, 2013) – Port Mast 4A
- Increment 36 (June 24, 2013) - Starboard Mast 1A, 3A, 1B, 3B
- Increment 38 (November 21, 2013) – Port Mast 2A, 2B, 4A, 4B
- Increment 40 (June 19, 2014) - Starboard SAW Mast 3A, 1B
- Increment 40 (August 18, 2014) - Starboard SAW Mast 3A, 1A, 1B, 3B
- Increment 41 (October 22, 2014) - Starboard SAW Mast 3A, 1A, 1B, 3B
- Increment 44 (August 10, 2015) – Starboard SAW Mast 1A, 3B
- Increment 45 (November 18, 2015) – Port SAW Mast 2A, 2B, 4A, 4B
- Increment 46 (February 3, 2016) – Starboard SAW Mast 3A, 1B
- Increment 50 (December 8, 2016) - Port SAW Mast 2A, 4A, 2B, 4B

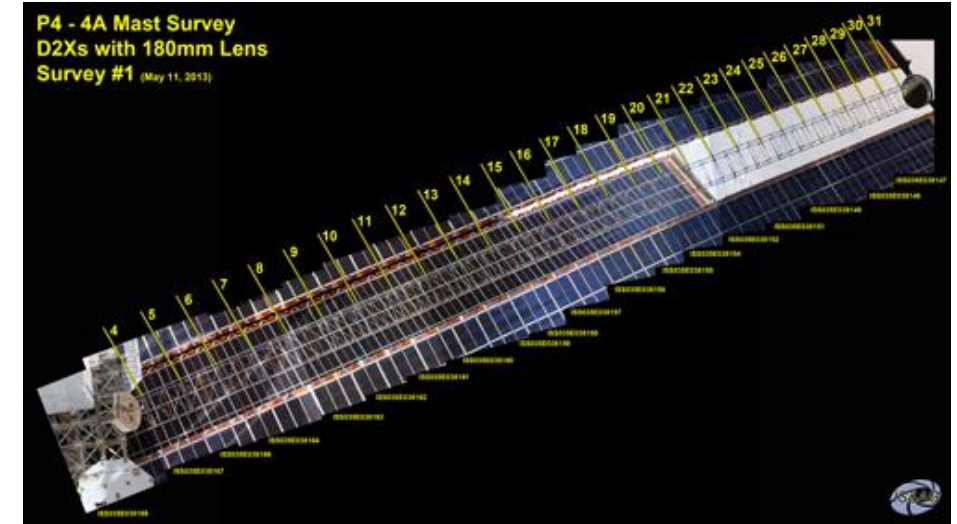
Red – Port SAW Mast

Green – STBD SAW Mast

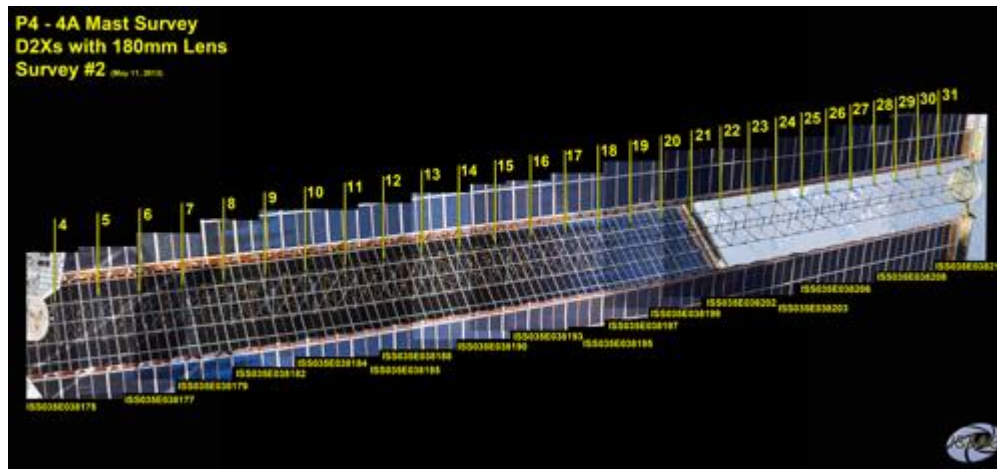


P4-4A Mast Survey

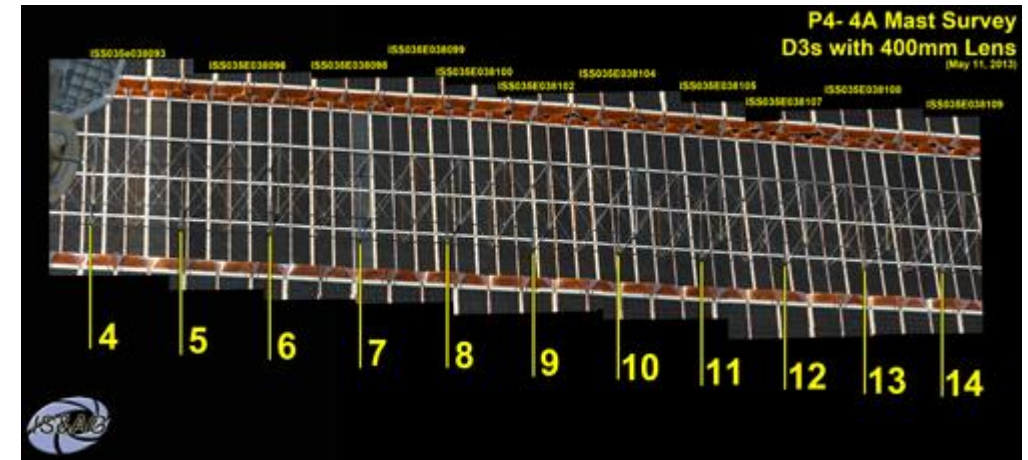
On May 11, 2013, during US EVA 21, Inc 35 Commander Chris Hadfield took images of the P4-4A Solar Array Wing (SAW) Mast from Window 1 in the Cupola using a Nikon D2Xs with a 180mm and 400mm lens.



P4-4A Mast Survey #1
From Cupola using D2Xs w/180mm



P4-4A Mast Survey #2
From Cupola using D2Xs w/180mm



P4-4A Mast Survey
From Cupola using D3Xs w/400mm



Lessoned Learned

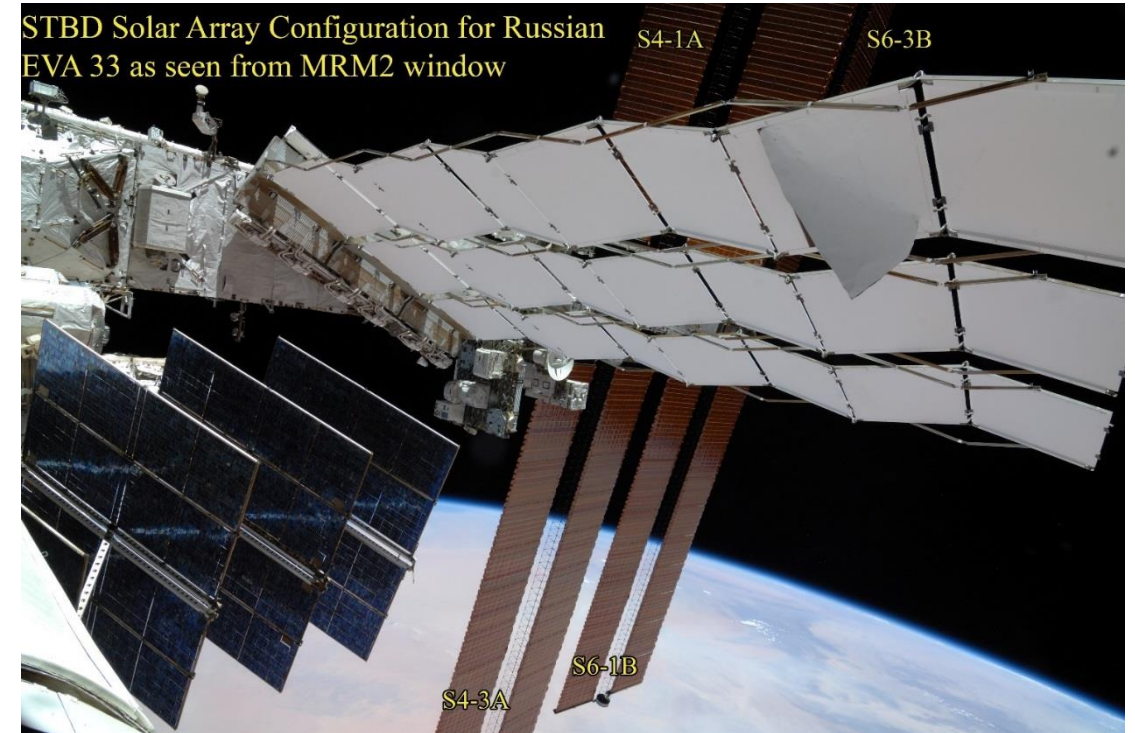
- Increment 35 (May 11, 2013) – Port Mast 4A
 1. Need to have dedicated time for pictures.
 2. Need to use the 400mm lens for adequate resolution.
 3. Verify that SAWs are not blocked or have other arrays behind them.
 4. The solar array rotating joints are locked in required viewing position.

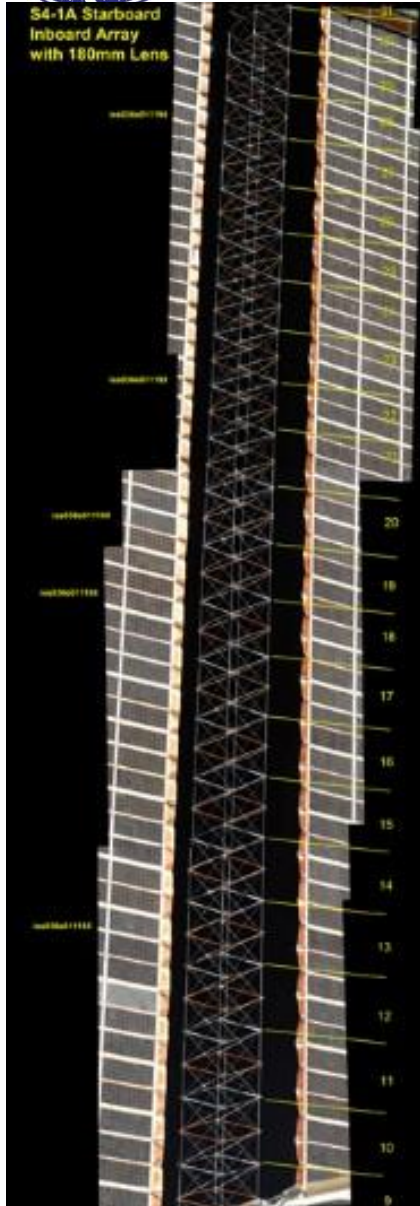


S4-1A, S4-3A, S6-1B, S6-3B Mast Survey

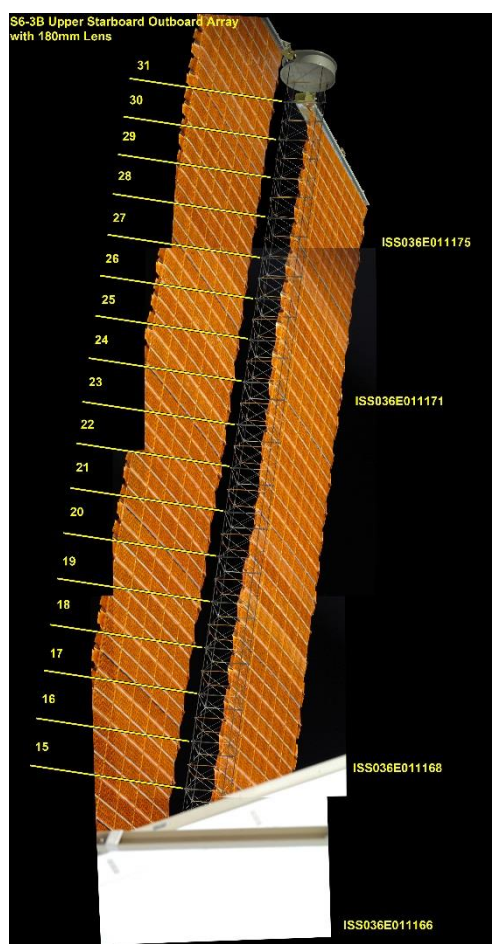


On June 24, 2013, Increment 36 Flight Engineer Chris Cassidy, performed a photo-survey of the STBD solar array masts using a Nikon D2Xs with a 180mm and 400mm lens. Cassidy took ~200 images while he was isolated in the MRM2 during Russian EVA 33.

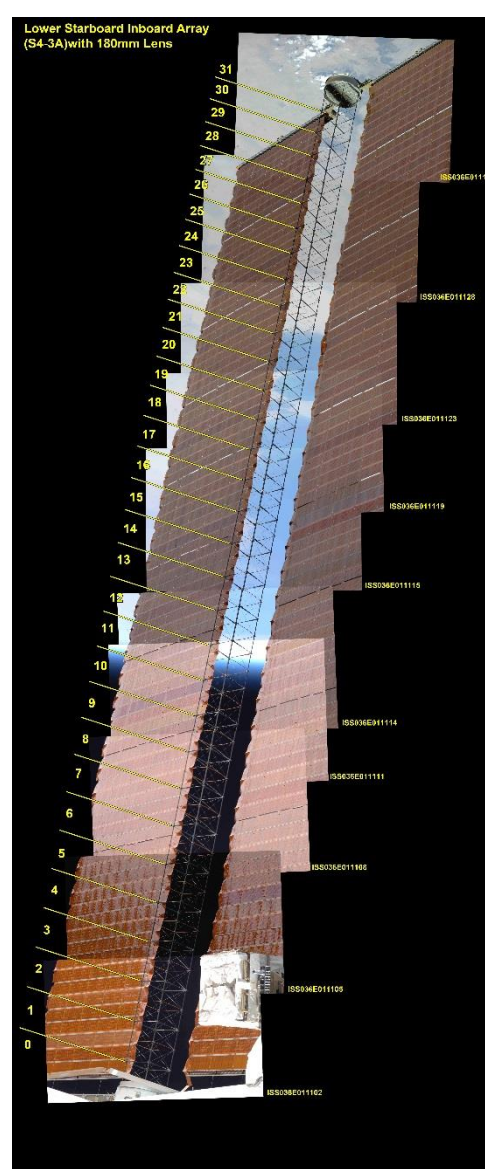




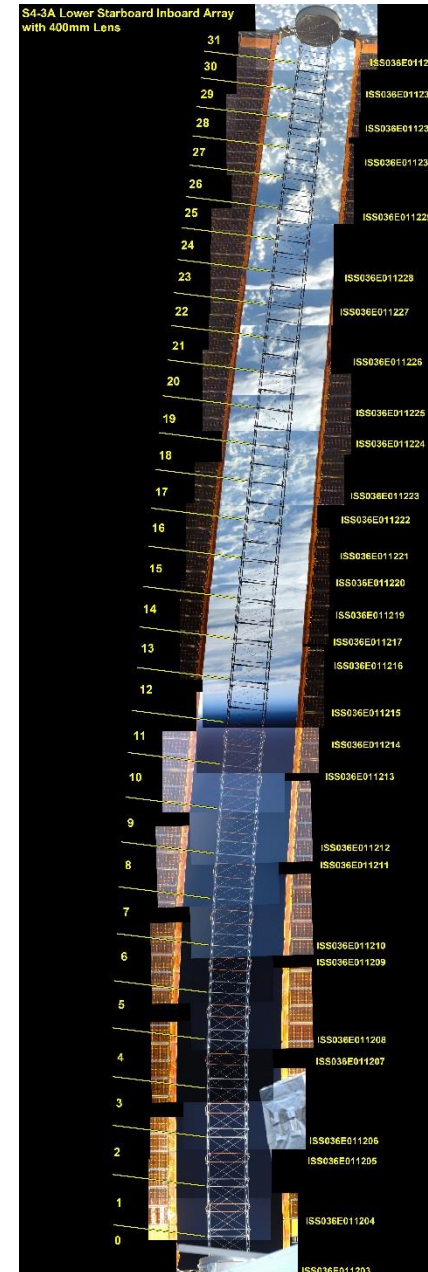
S6-3B Mast Survey
using D2Xs w/180mm



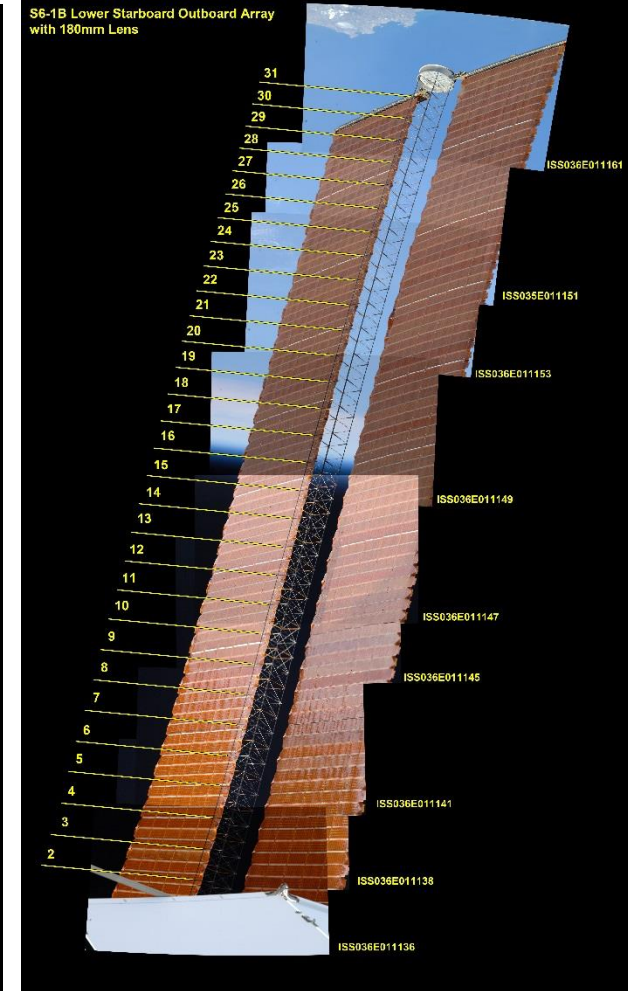
S4-3A Mast Survey
using D2Xs w/180mm



S4-3A Mast Survey
using D2Xs w/400mm



S4-1B Mast Survey
using D2Xs w/180mm





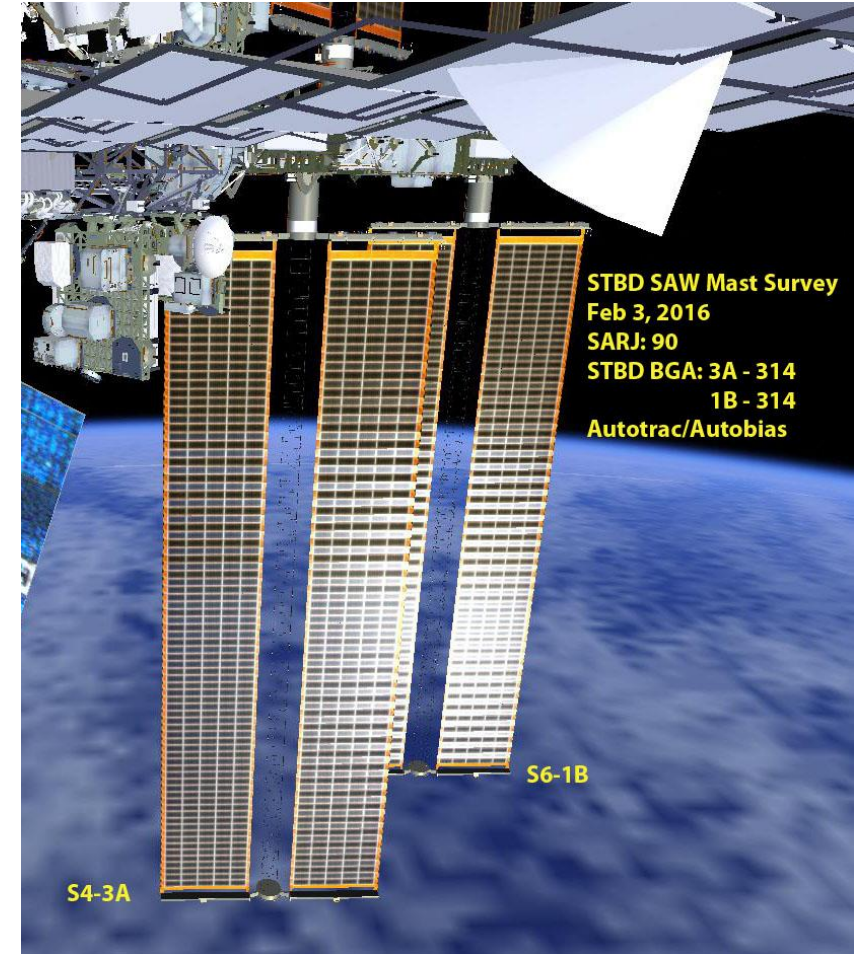
Lessons Learned

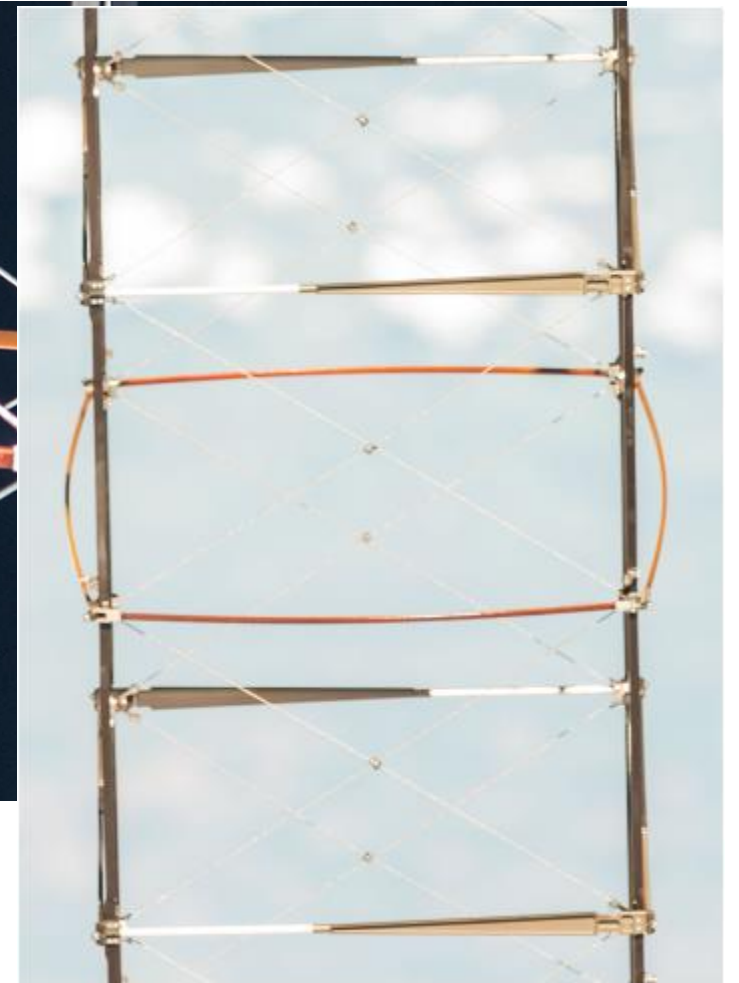
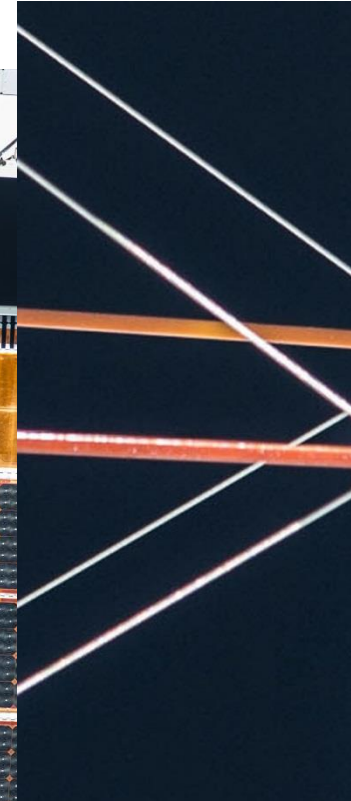
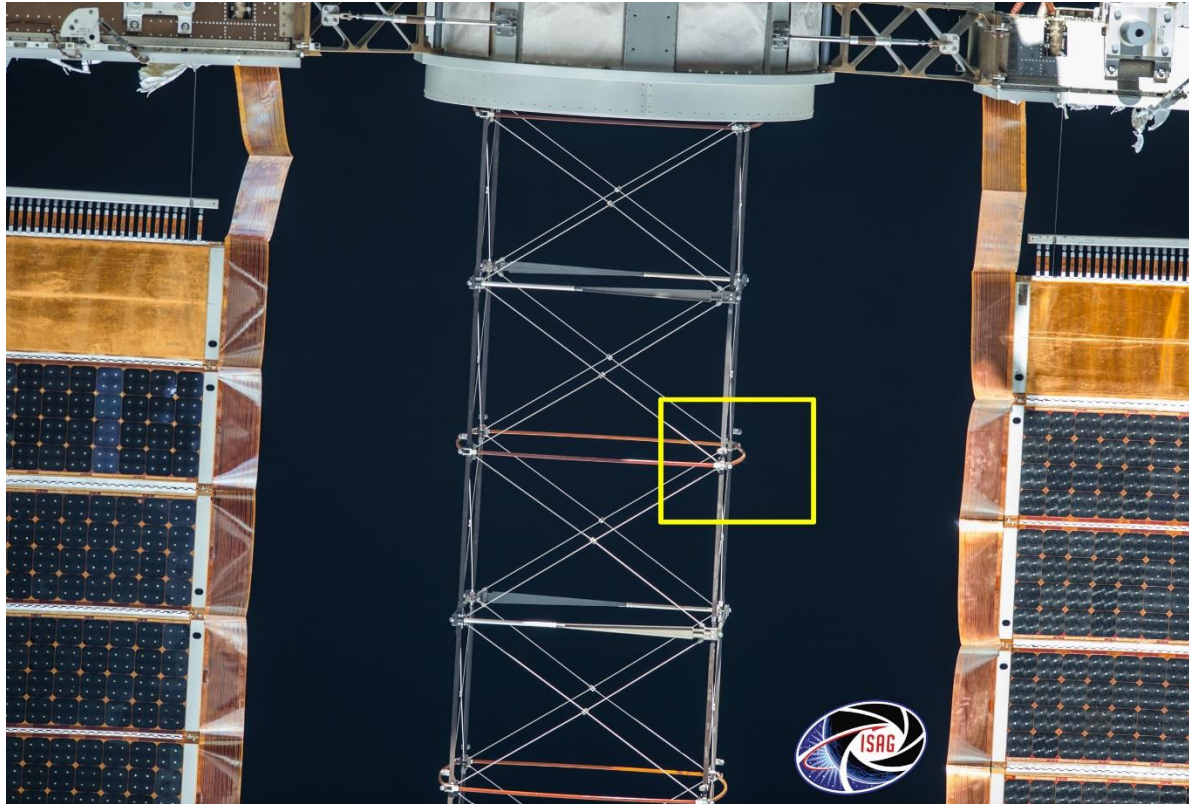
- Increment 36 (June 24, 2013) - Starboard Mast 1A, 3A, 1B, 3B
 - 1) Minimize overlapping of longerons.
 - 2) Verify procedures call out correct mast.



Inc 46 – Starboard SAW Mast Survey

This survey was the first attempt to have the crew take the images while the array's were in autotrack with an autobias?. The crew took the images a few minutes before the optimum time period. This resulted in a overlapping longerons on the inboard (3A mast).



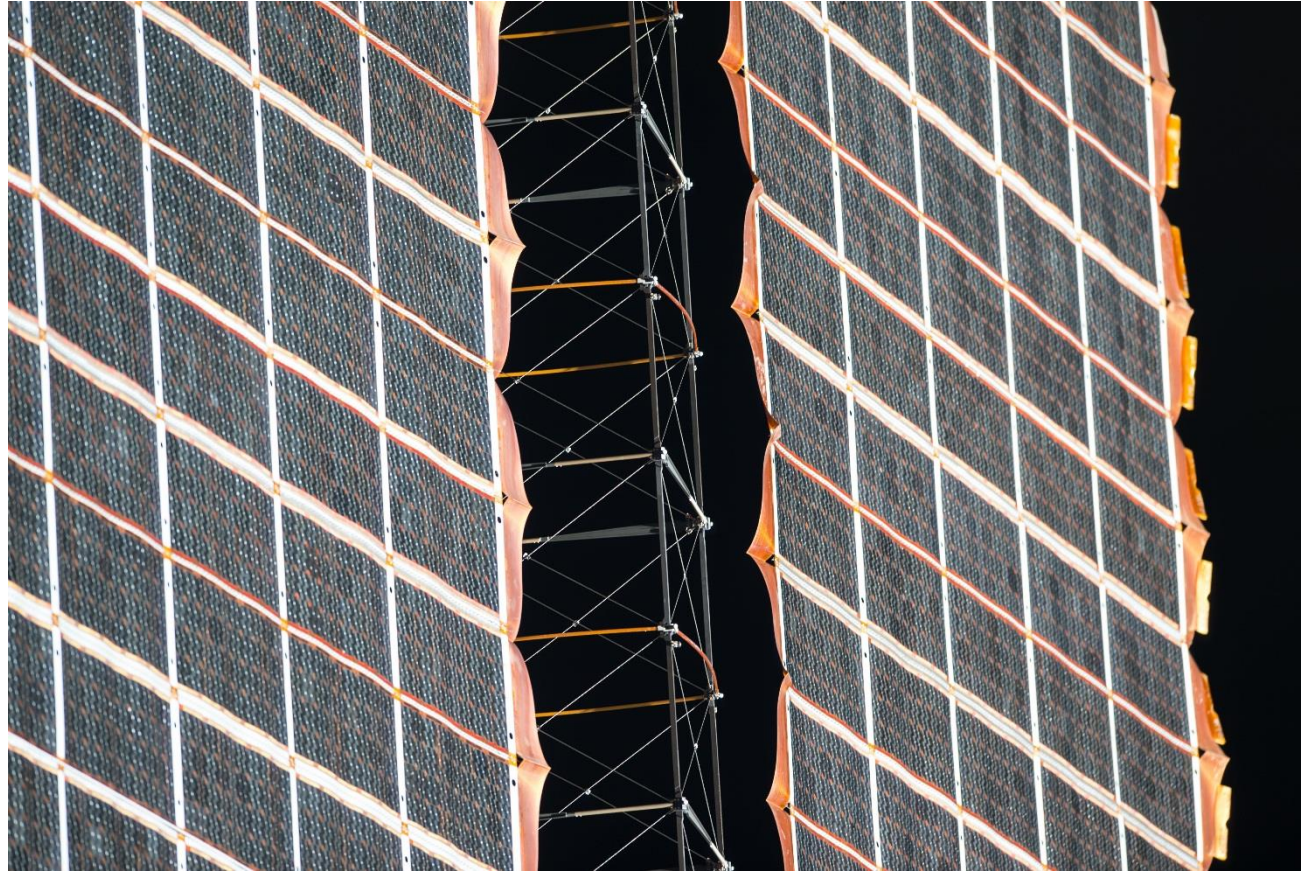


Lessons Learned –

Taking images while the SAW is in **autotrack** is possible, it is not the preferred method. If **autotracking** is used the crew must take the imagery at the designated time.



Why Arrays need to be parked.



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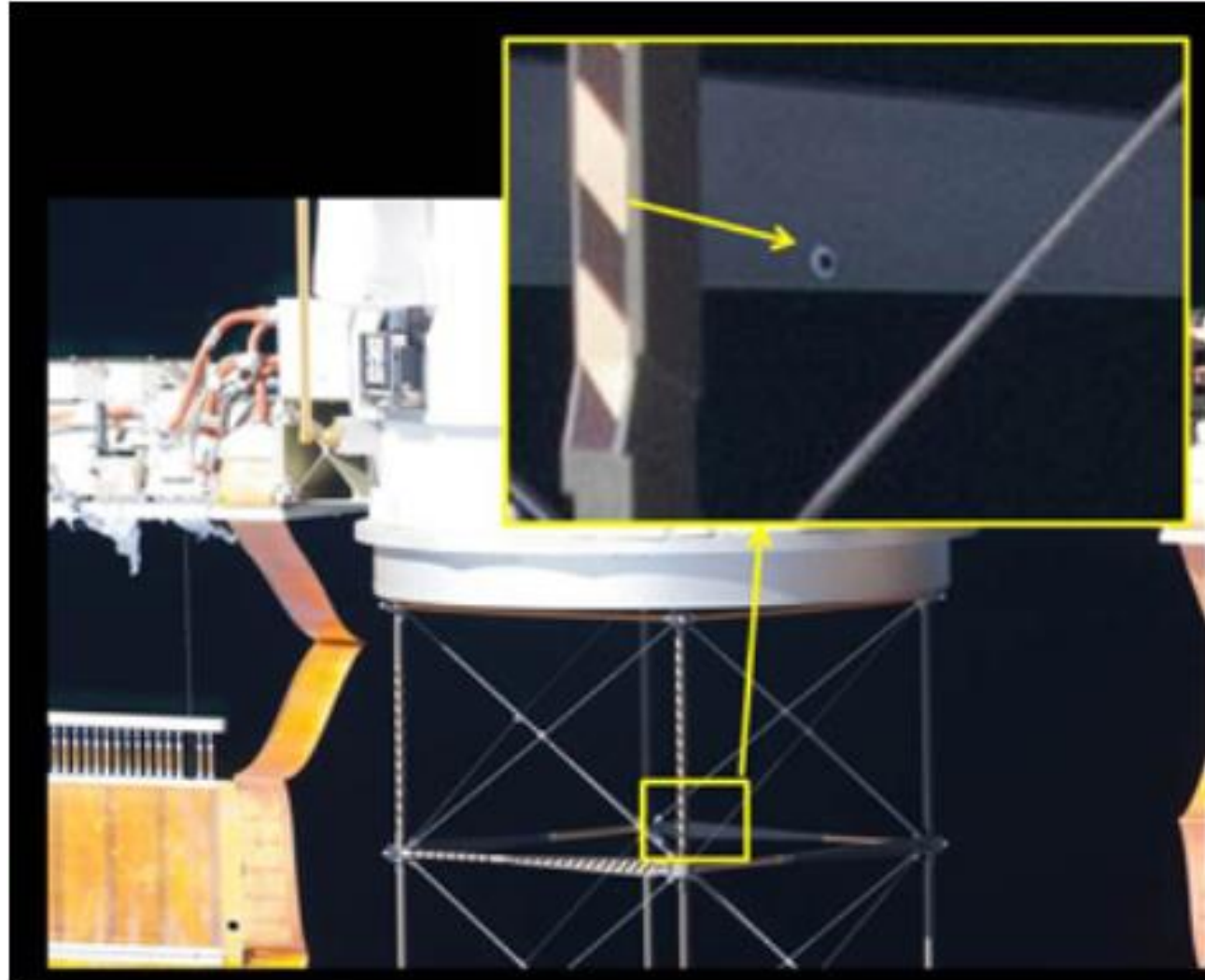


Example of Previous Findings

- 1) MMOD strike on P4-4A Rigid Batten
- 2) MMOD strike on P4-2A Flex Batten (side 1)
- 3) MMOD strike on P4-2A Flex Batten (side 2)
- 4) Area of Interest on Bay 4 Longeron and Rigid Batten.

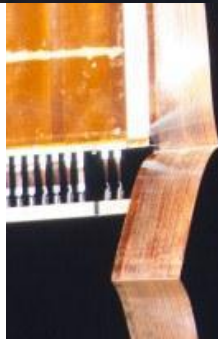
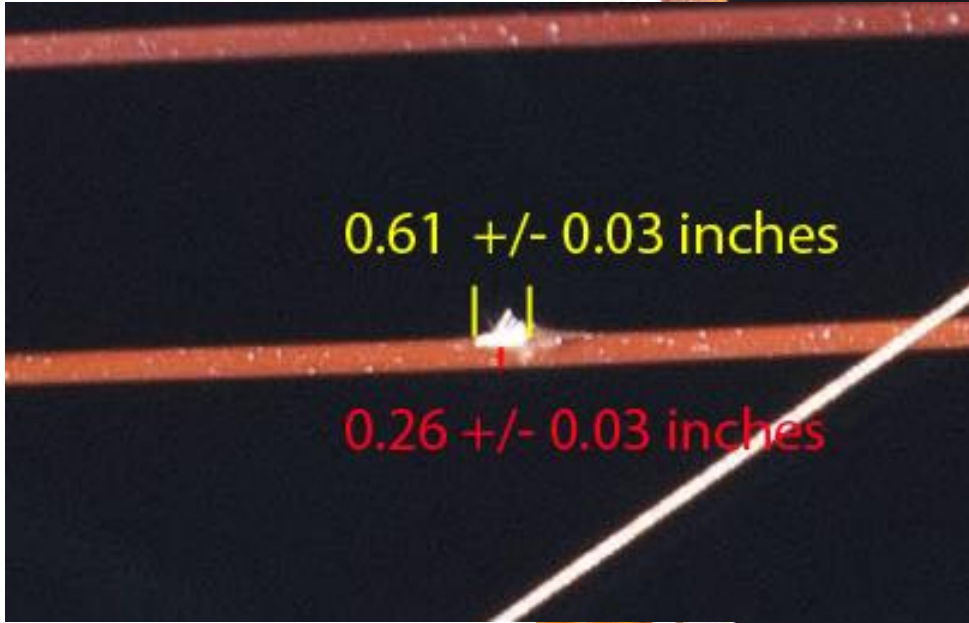


P4-4A SAW Mast Bay 0

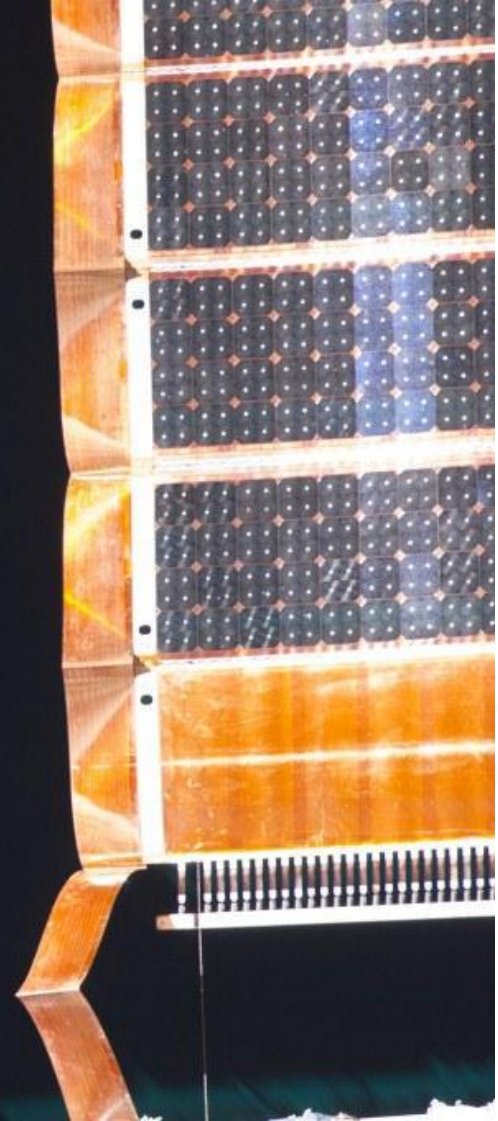
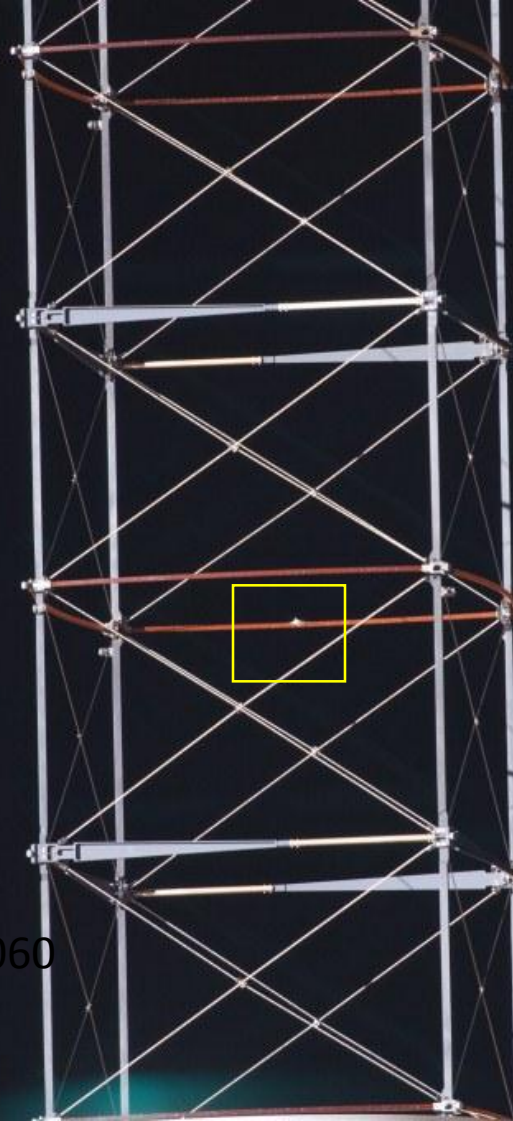




P4-2A SAW Mast Bay 1 (array in zenith position)

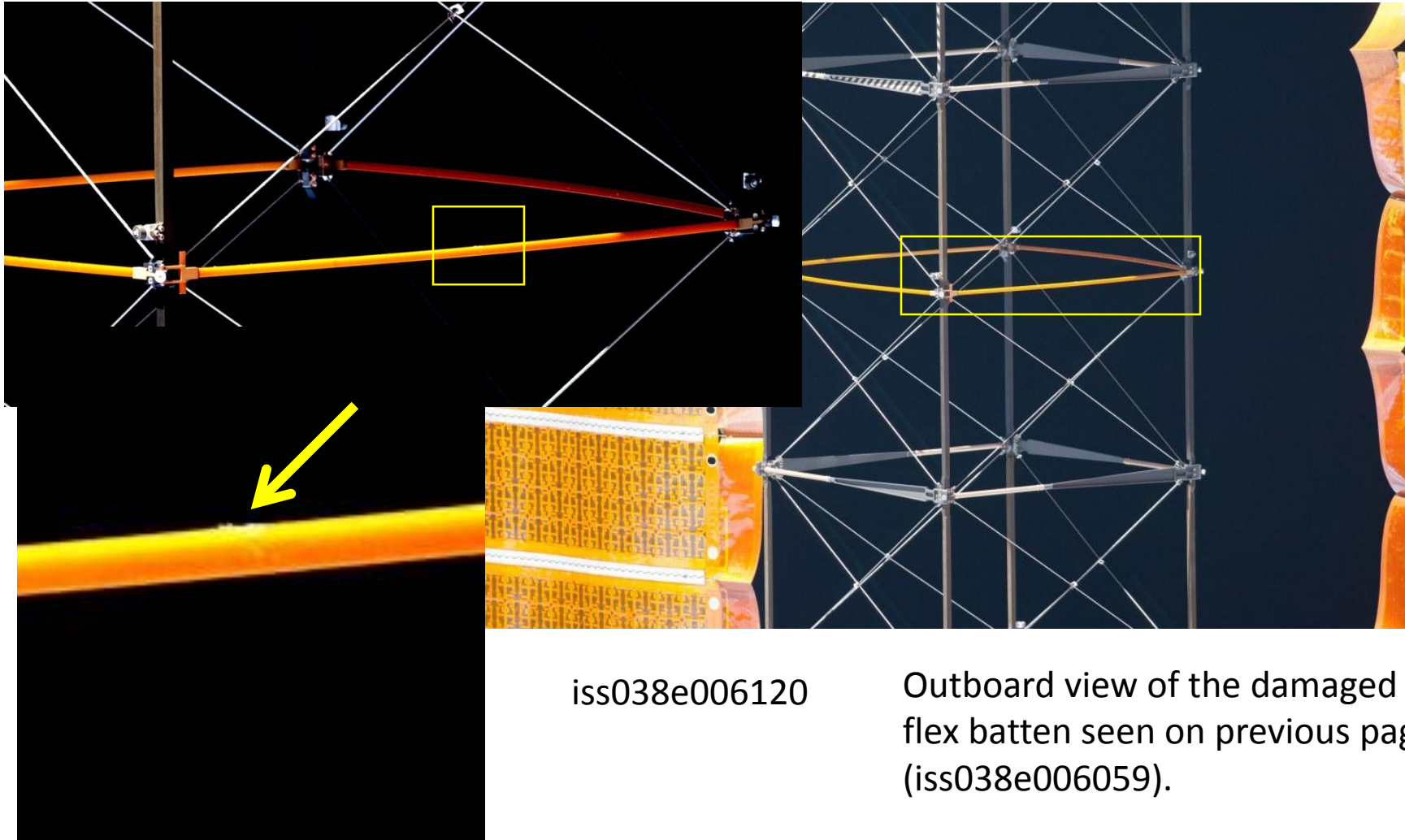


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P4-2A SAW Mast Bay 1 (array in nadir position)



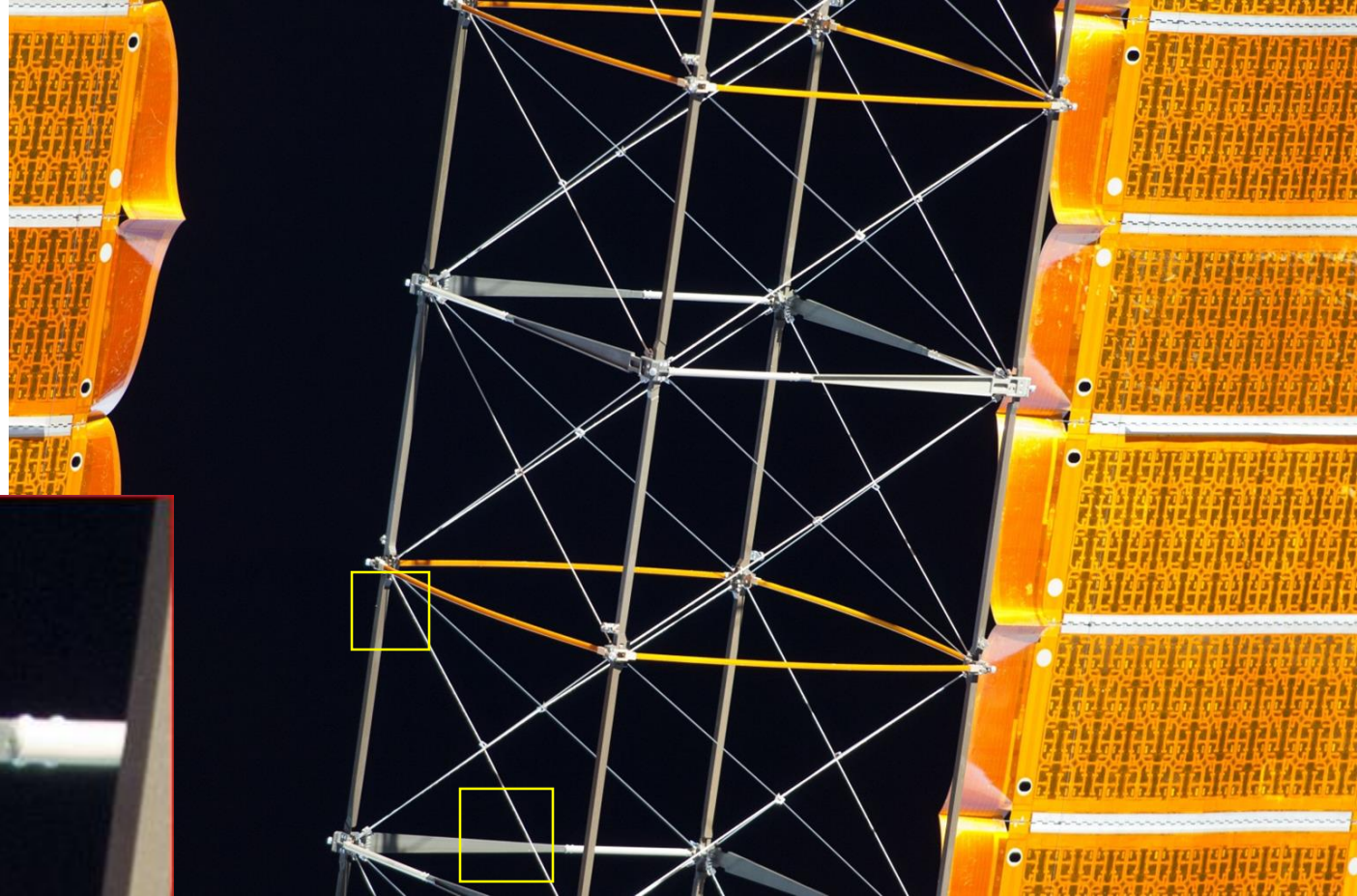
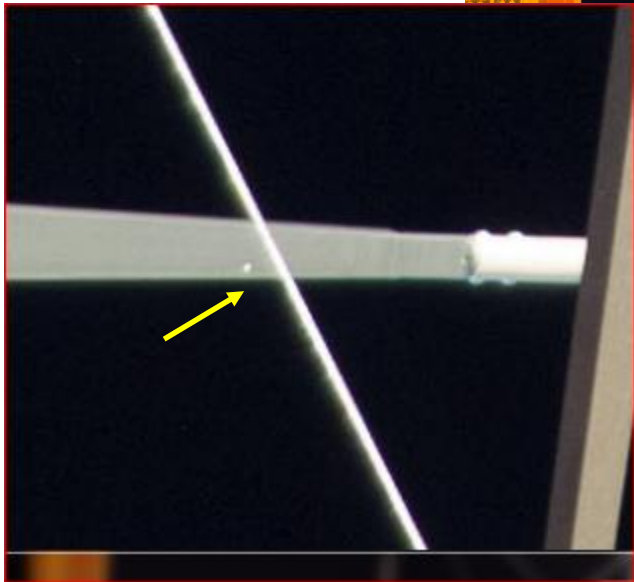
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Outboard view of the damaged
flex batten seen on previous page
(iss038e006059).



S4-3A - Bay 3, 4

AOI on Bay 4 Longeron and Rigid Batten



iss040e015222



Lessons Learned

1. If using crew, need to have dedicated time for photography.
2. Need 400mm lens to achieve adequate resolution.
3. Verify that SAW's are not blocked or have other arrays behind them.
4. The array masts should be locked in position.
5. Minimize over lapping of longerons.
6. Verify procedures call out correct mast.
7. Taking images while the SAW is in autotrack is possible, it is not the preferred method. If autotracking is used the crew must take the imagery at the designated time.



Future Inspection Issues

- Russian Docking Compartment is being replaced with the Russian Multipurpose Laboratory Module (MLM). Will require updated training and procedures because the MLM does not have windows.
- Crew time is limited. Can a robotic imaging system be used instead of the crew?